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CLAIMS

[Claim(s)]

[Claim 1] Divide incident light into the two linearly polarized lights the linearly polarized lights and the oscillating direction cross at right angles mutually, and one side is made into a reference beam. In a polarization interferometer which forms an interference fringe and takes out two-dimensional topology of a sample by compounding again and making it penetrate in order of a quarter-wave length board and a polarizer after making another side into sample light which passed through a sample A polarization interferometer which makes incident light before going into an interferometer the linearly polarized light, and is characterized by providing a means to rotate plane of polarization of this linearly polarized light in the direction of arbitration around an optical axis.

[Claim 2] A polarization interferometer according to claim 1 characterized by making it rotate plane of polarization of the linearly polarized light of incident light in the direction of arbitration around an optical axis by making incident light before going into an interferometer into the linearly polarized light, and letting 1/2 still more pivotable wavelength plate around an optical axis pass.

[Claim 3] A polarization interferometer according to claim 1 which makes incident light the linearly polarized light and is characterized by making it rotate plane of polarization of this linearly polarized light in the direction of arbitration around an optical axis by having the light source which generates the linearly polarized light, and rotating that light source around an optical axis.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001] [Industrial Application] This invention uses a polarization interferometer, detects and calculates gap of the phase of light at high degree of accuracy and a high speed, is 2-dimensional information acquisition equipment which measures field configurations, such as an ultra-

precision machining product, temperature distribution, refractive-index distribution, plasma density, etc. in the real time, especially relates to an incident light study system portion.

[0002] [Description of the Prior Art] The 2-dimensional information acquisition equipment which used the interferometer as equipment which measures refractive-index distribution, temperature distribution, and 2-dimensional distribution of the physical quantity which changes in time like plasma density in the real time is proposed (refer to JP,2-287107,A). When this wants to observe the situation for example, on the surface of a sample, To take arrangement of a Michelson interferometer as shown in drawing 5, and observe the situation inside a sample Take arrangement of a Mach-Zehnder interferometer as shown in drawing 6, and divide the light from a laser light source 11 into the two linearly polarized lights the linearly polarized lights and the polarization direction cross at right angles mutually by polarization beam splitter PBS through a lens system 12, while it considers as a reference beam. Another side irradiates the measuring plane 14-ed (object) (19) as a sample light, and is again made into the one flux of light by polarization beam splitter PBS. However, the way things stand, since the plane of polarization of a reference beam and sample light lies at right angles mutually, interference is not caused. Then, the quarter-wave length board QWP3 set up in the 45-degree direction from a x axis and the y-axis and WP4 It is made to penetrate, the two linearly polarized lights are changed into the circular polarization of light of respectively right and left, and it is polarizer P1 -P3 further. It is interference fringe I1 -I3 by letting it pass. It makes. If a, phi x, and the amplitude and phase of a reference beam (the direction of S polarization y) are set [the P polarization direction and the S polarization direction of polarization beam splitter PBS] to b and phi y for the amplitude and phase of sample light (P polarization; x directions) for a x axis and the y-axis, respectively, Transmitted light reinforcement of the light which penetrated the polarizer which set transparency shaft orientations as theta I= (a²+b²) / 2+ab sin (phix-phiy+2theta) (1)
It becomes. Polarizer P1 -P3 When Direction theta is set as 0 degree, 45 degrees, and 90 degrees, respectively, transmitted light reinforcement is each. I1 = (a²+b²) / 2+ab sin (phix-phiy) (2)
I2 = (a²+b²) / 2+ab cos (phix-phiy) (3)
I3 = (a²+b²) / 2-ab sin (phix-phiy) (4)

Since it becomes, it is the phase contrast between a reference beam and sample light. +pi [phi x-phi y= tan-1 { / (I1-I2) /// / } (I2-I3)]/4 (5)

It is come out and given. Namely, the interference fringe I1 which is three from which 90 degrees of phases differ at a time, I2, and I3 After taking a photograph to coincidence with the television cameras TV1-TV3 with which frequency synchronized and searching for the difference signal of those video signals with a signal processor 17, two-dimensional phase distribution of measuring planes-ed (object), such as refractive-index distribution, temperature distribution, and plasma density, can be measured in the real time by asking for an arc tangent.

[0003] [Problem(s) to be Solved by the Invention] (5) Since phi x-phi y is not dependent on the amplitude a and b of a reference beam and sample light so that clearly from a formula, phase distribution can be measured even if the intensity ratio of the 2 flux of lights is theoretically imbalanced. However, it is [actual] the background (it lays underground into a²+b²/2, and contrast falls extremely.) where a sine wave-like interference fringe is strong so that clearly [in the case of (a<<b) or its reverse (a>>b)] from (1) type in the reinforcement of a reference beam being more remarkably [than sample luminous intensity] strong. If the gain of detector sensitivity is adjusted so that the strong background may not be saturated, it will become difficult to detect an important interference fringe, and even if it carries out an operation like (5) types, exact measurement becomes impossible only in noises.

[0004] In case polarization division of the incident light is carried out, an optic is usually set up so that the luminous-intensity ratio which progresses to a light [which progresses to a reference mirror], and sample side may become one to one, but it is remarkable especially when measuring phase distribution of a sample with low permeability in the case where are easy to generate such a trouble when the output light reinforcement from sample light is low, and the shape of surface

type of a sample with a low reflection factor is measured in a Michelson interferometer, or a Mach-Zehnder interferometer.

[0005] In order to conquer such a failure, it is also possible to insert the extinction filter ND corresponding to the degree of a difference on the strength (to refer to drawing 6) in the optical path (usually reference beam side) of the one where reinforcement is strong, to maintain the balance of the 2 flux of light on the strength, and to prevent the fall of contrast. However, the situation where it is dark even if it raises the sensitivity of a detector, when the whole quantity of light will be lost and reinforcement of the light source cannot be raised by this method, and data processing was impossible was also caused.

[0006] This invention aims at obtaining the polarization interferometer which can raise the contrast of an interference fringe in view of the above troubles, without losing the whole quantity of light.

[0007] [Means for Solving the Problem] In order to attain the above-mentioned purpose, it sets to a polarization interferometer of this invention. Divide incident light into the two linearly polarized lights the linearly polarized lights and the oscillating direction cross at right angles mutually, and one side is made into a reference beam. An interference fringe is formed by compounding again and making it penetrate in order of a quarter-wave length board and a polarizer, after making another side into sample light which passed through a sample. It is the polarization interferometer which takes out two-dimensional topology of a sample, and incident light before going into an interferometer is made into the linearly polarized light, and a means to rotate plane of polarization of this linearly polarized light in the direction of arbitration around an optical axis is provided.

[0008] In order to make incident light before going into an interferometer into the linearly polarized light, it is also possible for the light source [as / whose polarization condition is the linearly polarized light from the first] to be used, and to make it install a polarizer immediately after that using the light source of random polarization, and to change light of the circular polarization of light into the linearly polarized light using a quarter-wave length board. Moreover, as a means to rotate plane of polarization of the linearly polarized light in the direction of arbitration around an optical axis, 1/2 pivotable wavelength plate may be installed in the surroundings of an optical axis, and the light source itself which generates the linearly polarized light may be rotated around an optical axis.

[0009] Furthermore, if polarization division of the incident light besides a Michelson interferometer and a Mach-Zehnder interferometer can be carried out in a reference beam and sample light at the 2 flux of lights and phase distribution of a sample can be measured as an interferometer, to say nothing of various kinds of interferometers being applicable, it is possible for it not to be limited to laser as the light source, but to use Na lamp, and a mercury-vapor lamp and a halogen lamp. Moreover, if a phase child can also give 180-degree phase contrast, the Babinet Soleil compensator, king prism, the Fresnel rhomb, etc. can also be used besides 1/2 wavelength plate.

[0010] [Function] Drawing 4 explains the polarization condition of the incident light in the polarization interferometer constituted as mentioned above. For example, if output light comes out by the gain of a:b from the difference in a reflection factor or permeability even if it distributes and inputs light into a sample light and reference beam side by the gain of one to one, the gain of output light can be made into one to one by adjusting the gain of the light inputted beforehand to b:a.

[0011] When rotating the light source which generates the linearly polarized light around a direct optical axis, it is the incidence linearly polarized light E0. The oscillating direction $\alpha = \tan^{-1}(a/b)$ (6)

What is necessary is just to set it as the angle to satisfy. On the other hand, in the case where 1/2 wavelength plate is used, the oscillating direction (angle α) of the incidence linearly polarized light carries out rotation adjustment of the oscillating direction by rotating the direction of the

phase leading shaft f of $1/2$ wavelength plate (angle β), fixed. Since the oscillating direction of the linearly polarized light is changed in the symmetrical direction about the phase leading shaft f of $1/2$ wavelength plate, oscillating direction EO' after $1/2$ wavelength-plate transparency consists of a x axis in the direction to which only the angle $(2\beta - \alpha)$ inclined. this -- $\tan(2\beta - \alpha) = a/b$ -- namely, -- $\beta = \{\alpha + \tan^{-1}(a/b)\}/2$ (7)

If rotation adjustment of the $1/2$ wavelength plate is carried out in the bearing to satisfy, the contrast of an interference fringe will become max.

[0012] [Example] It is the example which applied this invention to the Michelson interferometer used when this example measures the shape of surface type of a sample by the reflected light in drawing 1 hereafter to explain the polarization interferometer of this invention with reference to a drawing. Using the laser 11 which outputs the linearly polarized light to the light source, the light from this laser light source 11 is inserted immediately after that, it is divided into the two linearly polarized lights to which bearing with which are satisfied of (7) types, and the polarization direction cross at right angles mutually by polarization beam splitter PBS through $1/2$ wavelength plate HWP and lens system 12 by which rotation adjustment was carried out, and one side is a reference beam. The reference side 15 is irradiated, and another side irradiates the measuring plane 14-ed (sample) as a sample light, and is again compounded to the one flux of light by polarization beam splitter PBS. It is the quarter-wave length board QWP3 set up in the 45-degree direction from a x axis and the y -axis since the plane of polarization of a reference beam and sample light lay at right angles mutually the way things stand, and interference was not caused. It is made to penetrate and the two linearly polarized lights are changed into the circular polarization of light on either side, respectively. As shown in drawing 5 after an appropriate time, a polarization wave face is divided into three by the polarization wavefront-splitting optical system 16, and it is polarizer P1 -P3 further. They are interference fringes I1 -I3 by letting it pass. It makes. The interference fringe I1 which is three from which 90 degrees of these phases differ at a time, I2, and I3 After taking a photograph to coincidence with the television cameras TV1-TV3 with which frequency synchronized and searching for the difference signal of those video signals with a signal processor 17, by asking for an arc tangent, two-dimensional phase distribution of the measuring plane 14-ed is measured in the real time, and the measurement result is displayed on a display 18.

[0013] It is the example which applied this invention to the Mach-Zehnder interferometer used by it in case this example measures the phase distribution inside a sample by the transmitted light for drawing 2 to explain other examples. The laser 13 which outputs random polarization is used for the light source, and it is a polarizer P4 immediately after that. It considers as the linearly polarized light, and it inserts, $1/2$ wavelength plate HWP is inserted continuously, and rotation adjustment is carried out in the bearing with which are satisfied of (7) types. The light from a laser light source 13 is divided into the two linearly polarized lights the linearly polarized lights and the polarization direction cross at right angles mutually by polarization beam splitter PBS through these polarizers P4, $1/2$ wavelength plate HWP, and a lens system 12. By one side considering as a reference beam, another side irradiates the transparency body (sample) 19 as a sample light, and is again compounded to the one flux of light by polarization beam splitter PBS, and it is the quarter-wave length board QWP4. As it is made to penetrate and is shown in drawing 6 after an appropriate time A polarization wave face is divided into three by the polarization wavefront-splitting optical system 16, and it is polarizer P1 -P3 further. It lets it pass. Interference fringe I1 -I3 It makes. The interference fringe I1 which is three from which 90 degrees of these phases differ at a time, I2, and I3 After taking a photograph to coincidence with the television cameras TV1-TV3 with which frequency synchronized and searching for the difference signal of those video signals with a signal processor 17, by asking for an arc tangent, the two-dimensional phase distribution inside the transparency body (sample) 19 is measured in the real time, and the measurement result is displayed on a display 18.

[0014] It is what this example possessed the device 20 in which that laser 11 was rotated around

an optical axis in drawing 1 example using the laser 11 which outputs the linearly polarized light as the light source for drawing 3 to explain the example of further others, and carried out rotation adjustment of the laser 11 main part in the bearing with which are satisfied of (6) types, and other configurations are the same as that of drawing 1 example.

[0015] [Effect of the Invention] Since this invention is constituted as explained above, by rotating the plane of polarization of the incidence linearly polarized light in the direction of arbitration around an optical axis, it can change continuously the rate of the light divided into a reference and sample side, can set it as the optimal quantity of light ratio, and can raise the contrast of an interference fringe. Although there was a method which permeability sets as the optimal permeability using the extinction filter which changes continuously also conventionally, when it was not able to be set as the uniform quantity of light over the whole surface of the two-dimensional observation field of a sample, but a large field was observed, the nonuniformity of an interference fringe arose and contrast was doubled with the specific location, now, it had lapsed into the dilemma that the contrast of other locations falls. However, in this invention, adjustment of the quantity of light is made in rear-spring-supporter homogeneity on all over an observation field, and the ununiformity of contrast is not started at all. Of course, in this invention, since an extinction filter is not used, the quantity of light is not lost and all the light from the light source can be used. Therefore, even if it uses the light source of a small output, an image is bright, the accuracy of measurement improves and the miniaturization of a measuring beam study system is also attained. Furthermore, in this invention, since it can perform freely supplying light only to one side by the side of a reference beam and sample light, also in case the condition of an optical path is checked, convenience is good, and also when it is optical adjustment of an interferometer, there is also a secondary effect of being convenient.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is drawing showing the optical-system important section using $1/2$ wavelength plate with the one example equipment of this invention.

[Drawing 2] It is drawing showing the optical-system important section using a polarizer and $1/2$ wavelength plate with other example equipments of this invention.

[Drawing 3] It is drawing showing the optical-system important section possessing the device in which the laser light source which generates the linearly polarized light is directly rotated with the example equipment of further others of this invention.

[Drawing 4] It is drawing showing the condition of polarization bearing in this invention.

[Drawing 5] It is the block diagram showing the field configuration gaging system using a polarization Michelson interferometer with conventional 2-dimensional information acquisition equipment.

[Drawing 6] It is the block diagram showing the transparence body gaging system using a polarization Mach-Zehnder interferometer with conventional 2-dimensional information acquisition equipment.

[Description of Notations]

11 -- Laser light source (linearly polarized light) 12 -- Lens system

13 -- Laser light source (random polarization) 14 -- Measuring plane-ed

15 -- Reference side 16 -- Polarization wavefront-splitting optical system

5 17 -- Signal processor 18 -- Display

19 -- Transparence body 20 -- Laser rolling mechanism

PBS -- Polarization beam splitter QWP1-QWP4 -- Quarter-wave length board

HWP -- 1/2 wavelength plate P1-P4 -- Polarizer

TV1-TV3 -- Television camera I1-I3 -- Interference fringe

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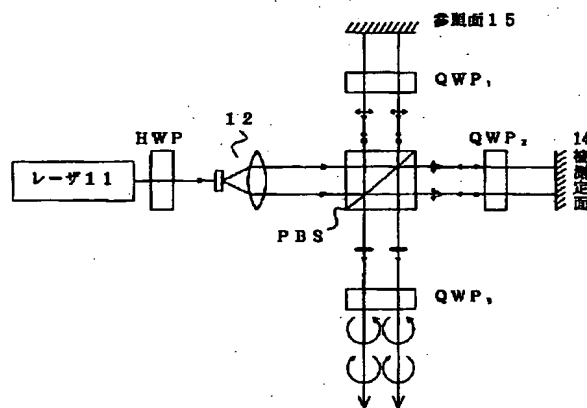
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(54)【発明の名称】 偏光干渉計

(57)【要約】 (修正有)

【目的】 全体の光量を損失することなく干渉縞のコントラストを上げる偏光干渉計の提供。

【構成】 直線偏光を出力するレーザ光源11からの光はその直後に挿入された1/2波長板HWP及びレンズ系12を経て偏光ビームスプリッタPBSで偏光方向が互いに直交する二つの直線偏光に分けられ、一方は参照光として参照面15を照射し、他方は試料光として被測定面(サンプル)14に照射して、再び偏光ビームスプリッタPBSで一つの光束に合成する。このとき、x軸、y軸から45°の方向に設定された1/4波長板QWP3を透過させて二つの直線偏光を夫々左右の円偏光に変換する。



【特許請求の範囲】

【請求項1】 入射光を振動方向が互いに直交する二つの直線偏光に分割して一方を参照光とし、他方をサンプルを経た試料光とした後、再び合成し1/4波長板、偏光子の順に透過させることによって干渉縞を形成し、サンプルの二次元的な位相情報を取り出す偏光干渉計において、

干渉計に入る前の入射光を直線偏光とし、この直線偏光の偏光面を光軸の回りに任意の方向に回転させる手段を具備したことを特徴とする偏光干渉計。

【請求項2】 干渉計に入る前の入射光を直線偏光とし、更に光軸の回りに回転可能な1/2波長板を通すことにより、入射光の直線偏光の偏光面を光軸の回りに任意の方向に回転させるようにしたことを特徴とする請求項1記載の偏光干渉計。

【請求項3】 直線偏光を発生する光源を備え、その光源を光軸の回りに回転させることにより、入射光を直線偏光とし、この直線偏光の偏光面を光軸の回りに任意の方向に回転させるようにしたことを特徴とする請求項1記載の偏光干渉計。

【発明の詳細な説明】

【0001】

【産業上の利用分野】 本発明は偏光干渉計を用いて光の位相のズレを高精度かつ高速に検出、計算して、超精密加工製品等の面形状、温度分布、屈折率分布、プラズマ密度等を実時間で測定する二次元情報取得装置の特に入*

$$I = (a^2 + b^2) / 2 + ab \sin(\phi x - \phi y + 2\theta) \quad (1)$$

となる。偏光子P1～P3の方向 θ を0°、45°、90°に夫々設定すると、透過光強度は夫々

$$I1 = (a^2 + b^2) / 2 + ab \sin(\phi x - \phi y) \quad (2)$$

$$I2 = (a^2 + b^2) / 2 + ab \cos(\phi x - \phi y) \quad (3)$$

$$I3 = (a^2 + b^2) / 2 - ab \sin(\phi x - \phi y) \quad (4)$$

となるので、参照光と試料光の間の位相差は

$$\phi x - \phi y = \tan^{-1} \{ (I1 - I2) / (I2 - I3) \} + \pi / 4 \quad (5)$$

で与えられる。即ち、位相が90°ずつ異なる三つの干渉縞I1、I2、I3を周波数の同期したテレビカメラTV1～TV3で同時に撮影し、信号処理装置17でそれらのビデオ信号の差信号を求めた後に逆正接を求めることによって、屈折率分布、温度分布やプラズマ密度等の被測定面(物)の二次元的な位相分布を実時間で測定することができる。

【0003】

【発明が解決しようとする課題】 (5)式から明らかなように、 $\phi x - \phi y$ は参照光と試料光の振幅a、bに依存しないので、原理的には二光束の強度比がアンバランスでも位相分布を測定することができる。しかし、実際には、例えば、参照光の強度が試料光の強度より著しく強かったり($a \ll b$)、或いはその逆の場合($a \gg b$)には、(1)式から明らかなように、正弦波状の干渉縞が強いバックグラウンド($a^2 + b^2 / 2$ の中に埋

*射光学系部分に関する。

【0002】

【従来の技術】 屈折率分布や温度分布、プラズマ密度等のように時間的に変化する物理量の二次元分布を実時間で測定する装置として干渉計を利用した二次元情報取得装置が提案されている(特開平2-287107号公報参照)。これは、例えば、サンプル表面の様子を観察したいときには、第5図に示すようなマイケルソン干渉計の配置をとり、サンプル内部の様子を観察したいときには、第6図に示すようなマッハツェンダー干渉計の配置をとって、レーザ光源11からの光をレンズ系12を経て偏光ビームスプリッタPBSで偏光方向が互いに直交する二つの直線偏光に分け一方は参照光とし、他方は試料光として被測定面(物)14(19)に照射し、再び偏光ビームスプリッタPBSで一つの光束にする。しかし、このままでは参照光と試料光の偏光面は互いに直交しているため、干渉は起こさない。そこで、x軸、y軸から45°の方向に設定された1/4波長板QWP3、WP4を透過させて二つの直線偏光を夫々左右の円偏光に変換し、更に偏光子P1～P3を通すことによって干渉縞I1～I3を作る。偏光ビームスプリッタPBSのP偏光方向及びS偏光方向を夫々x軸、y軸にとり、試料光(P偏光;x方向)の振幅と位相を夫々a、 ϕx 、参照光(S偏光;y方向)の振幅と位相を夫々b、 ϕy とすると、透過軸方向を θ に設定した偏光子を透過した光の透過光強度は

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となる。偏光子P1～P3の方向 θ を0°、45°、90°に夫々設定すると、透過光強度は夫々

$$I1 = (a^2 + b^2) / 2 + ab \sin(\phi x - \phi y) \quad (2)$$

$$I2 = (a^2 + b^2) / 2 + ab \cos(\phi x - \phi y) \quad (3)$$

$$I3 = (a^2 + b^2) / 2 - ab \sin(\phi x - \phi y) \quad (4)$$

となるので、参照光と試料光の間の位相差は

【0004】 普通、入射光を偏光分割する際に、参照鏡に進む光と試料側へ進む光の強度比が1対1になるように光学部品の設定を行うが、試料光からの出力光強度が低い場合にこのようなトラブルが発生しやすく、マイケルソン干渉計では反射率の低いサンプルの表面形状を測定する場合やマッハツェンダー干渉計では透過率の低いサンプルの位相分布を測定する場合に特に顕著である。

【0005】 このような障害を克服するために、強度の強い方の光路(通常、参照光側)に強度差の程度に見合った減光フィルタND(第6図参照)を挿入し、二光束の強度バランスをとり、コントラストの低下を防止することも可能である。しかし、この方法では全体の光量を損失することになり、光源の強度を上げられない場合に

は検出器の感度を上げてても暗くて、演算処理ができないという事態も招いていた。

【0006】本発明は、上記のような問題点に鑑み、全体の光量を損失することなく干渉縞のコントラストを上げることができる偏光干渉計を得ることを目的としている。

【0007】

【課題を解決するための手段】上記目的を達成するため、本発明の偏光干渉計においては、入射光を振動方向が互いに直交する二つの直線偏光に分割して一方を参照光とし、他方をサンプルを経た試料光とした後、再び合成し1/4波長板、偏光子の順に透過させることによって干渉縞を形成し、サンプルの二次元的な位相情報を取り出す偏光干渉計であって、干渉計に入る前の入射光を直線偏光とし、この直線偏光の偏光面を光軸の回りに任意の方向に回転させる手段を具備したものである。

【0008】干渉計に入る前の入射光を直線偏光とするためには、偏光状態がもともと直線偏光であるような光源を用いてもよく、また、ランダム偏光の光源を用いてその直後に偏光子を設置するようにしてもよいし、円偏光の光を1/4波長板を用いて直線偏光に変換することも可能である。また、直線偏光の偏光面を光軸の回りに任意の方向に回転させる手段としては光軸の回りに回転*

$$\alpha = \tan^{-1}(a/b)$$

を満足する角度に設定すればよい。他方、1/2波長板を用いる場合は、入射直線偏光の振動方向(角 α)は固定したままで1/2波長板の進相軸fの方向(角 β)を回転させることによって振動方向を回転調整する。直線偏光の振動方向は1/2波長板の進相軸fに関して対※

$$\beta = \{\alpha + \tan^{-1}(a/b)\} / 2$$

を満足する方位に1/2波長板を回転調整すると干渉縞のコントラストは最大になる。

【0012】

【実施例】以下、本発明の偏光干渉計について図面を参照して説明するに、第1図において、この実施例は反射光でサンプルの表面形状を測定するときに用いられるマイケルソン干渉計に本発明を適用した例である。光源には直線偏光を出力するレーザ11を用い、同レーザ光源11からの光はその直後に挿入され、(7)式を満足する方位に回転調整された1/2波長板HWP及びレンズ系12を経て偏光ビームスプリッタPBSで偏光方向が互いに直交する二つの直線偏光に分けられ、一方は参照光として参照面15を照射し、他方は試料光として被測定面(サンプル)14に照射して、再び偏光ビームスプリッタPBSで一つの光束に合成する。このままでは参照光と試料光の偏光面は互いに直交しているため、干渉は起こさないので、x軸、y軸から45°の方向に設定された1/4波長板QWP3を透過させて二つの直線偏光を夫々左右の円偏光に変換する。しかる後、第5図に示されるように、偏光波面分割光学系16で偏光波面を

*可能な1/2波長板を設置してもよく、直線偏光を発生する光源そのものを光軸の回りに回転させてもよい。

【0009】更に、干渉計としては、マイケルソン干渉計、マッハツェンダー干渉計の他、入射光を参照光と試料光に二光束に偏光分割して試料の位相分布を測定することができるものであれば各種の干渉計が適用できることはいうまでもなく、光源としてもレーザに限定されず、Naランプや水銀灯、ハロゲンランプを用いることも可能である。また、位相子も180°の位相差を与えることができるものであれば、1/2波長板の他にバビネソレイユ補償板、キングプリズム、フレネルロム等を用いることもできる。

【0010】

【作用】上記のように構成された偏光干渉計における入射光の偏光状態を第4図により説明する。例えば、試料光側と参照光側に一对一の振幅比で光を分配して入力しても出力光が反射率や透過率の違いからa:bの振幅比で出てくるのであれば、予め入力する光の振幅比をb:aに調整しておくことにより出力光の振幅比を一对一とすることができる。

【0011】直線偏光を発生する光源を直接光軸の回りに回転させる場合には、入射直線偏光E0の振動方向は

(6)

※称な方向に変換されるので、1/2波長板透過後の振動方向E0'はx軸から角(2 β - α)だけ傾いた方向になる。これが

$$\tan(2\beta - \alpha) = a/b$$

即ち

(7)

三つに分割し、更に偏光子P1~P3を通すことによって干渉縞I1~I3を作る。これら位相が90°ずつ異なる三つの干渉縞I1、I2、I3を周波数の同期したテレビカメラTV1~TV3で同時に撮影し、信号処理装置17でそれらのビデオ信号の差信号を求めた後に逆正接を求めることによって、被測定面14の二次元的な位相分布を実時間で測定し、その測定結果を表示装置18に表示する。

【0013】他の実施例を第2図により説明するに、この実施例は透過光でサンプルの内部の位相分布を測定する際に用いられるマッハツェンダー干渉計に本発明を適用した例である。光源にはランダム偏光を出力するレーザ13を用い、その直後に偏光子P4を挿入して直線偏光とし、続いて1/2波長板HWPを挿入し、(7)式を満足する方位に回転調整する。レーザ光源13からの光は、これら偏光子P4、1/2波長板HWP及びレンズ系12を経て偏光ビームスプリッタPBSで偏光方向が互いに直交する二つの直線偏光に分けられ、一方は参照光とし、他方は試料光として透明物体(サンプル)19に照射して、再び偏光ビームスプリッタPBSで一つ

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の光束に合成し、 $1/4$ 波長板QWP4を透過させ、しかる後、第6図に示されるように、偏光波面分割光学系16で偏光波面を三つに分割し、更に偏光子P1～P3を通すことによって干渉縞I1～I3を作る。これら位相が 90° ずつ異なる三つの干渉縞I1、I2、I3を周波数の同期したテレビカメラTV1～TV3で同時に撮影し、信号処理装置17でそれらのビデオ信号の差信号を求めた後に逆正接を求めることによって、透明物体(サンプル)19の内部の二次元的な位相分布を実時間で測定し、その測定結果を表示装置18に表示する。

【0014】さらに他の実施例を第3図により説明するに、この実施例は第1図実施例において、光源として直線偏光を出力するレーザ11を用い、そのレーザ11を光軸の回りに回転させる機構20を具備し、レーザ11本体を(6)式を満足する方位に回転調整したもので、その他の構成は第1図実施例と同様である。

【0015】

【発明の効果】本発明は以上説明したように構成されているので、入射直線偏光の偏光面を光軸の回りに任意の方向に回転させることによって参照側と試料側に分けられる光の割合を連続的に変えて最適の光量比に設定でき、干渉縞のコントラストを向上させることができる。従来でも透過率が連続的に変化する減光フィルタを用いて最適の透過率に設定する方法があったが、これではサンプルの二次元的な観察領域の全面にわたり均一な光量に設定することができず、広い領域を観察する場合には干渉縞のムラが生じ、特定の場所にコントラストを合わせると他の場所のコントラストが低下するといったジレンマに陥っていた。しかるに、本発明では観察領域全面にわたり均一に光量の調整ができ、コントラストの不均一は全くおこらない。勿論、本発明では減光フィルタを用いないので光量を損失することがなく、光源からの光は全て用いることができる。従って、小さな出力の光源を用いても画像は明るく、測定精度は向上し、測定光学

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系の小型化も可能になる。更に、本発明では、参照光側、試料光側的一方だけに光を供給することが自由のできるの、光路の状態を点検する際にも都合がよく、干渉計の光学調整のときにも便利であるという副次的効果もある。

【図面の簡単な説明】

【図1】本発明の一実施例装置で、 $1/2$ 波長板を用いた光学系要部を示す図である。

【図2】本発明の他の実施例装置で、偏光子と $1/2$ 波長板を用いた光学系要部を示す図である。

【図3】本発明の更に他の実施例装置で、直線偏光を発生するレーザ光源を直接回転させる機構を具備した光学系要部を示す図である。

【図4】本発明における偏光方位の状態を示す図である。

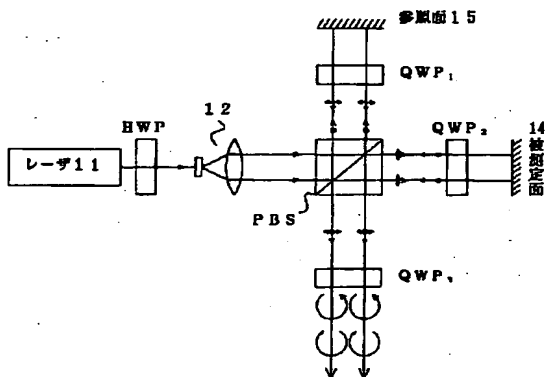
【図5】従来の二次元情報取得装置で、偏光マイケルソン干渉計を用いた面形状測定システムを示す構成図である。

【図6】従来の二次元情報取得装置で、偏光マッハツェンダー干渉計を用いた透明物体測定システムを示す構成図である。

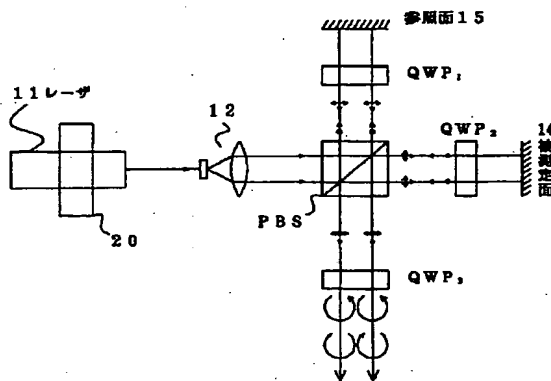
【符号の説明】

11…レーザ光源(直線偏光)	12…レンズ系
13…レーザ光源(ランダム偏光)	14…被測定面
15…参照面	16…偏光波面分割光学系
17…信号処理装置	18…表示装置
19…透明物体	20…レーザ回転機構
30 PBS…偏光ビームスプリッタ	QWP1～QWP4… $1/4$ 波長板
HWP… $1/2$ 波長板	P1～P4…偏光子
TV1～TV3…テレビカメラ	I1～I3…干渉縞

【図1】



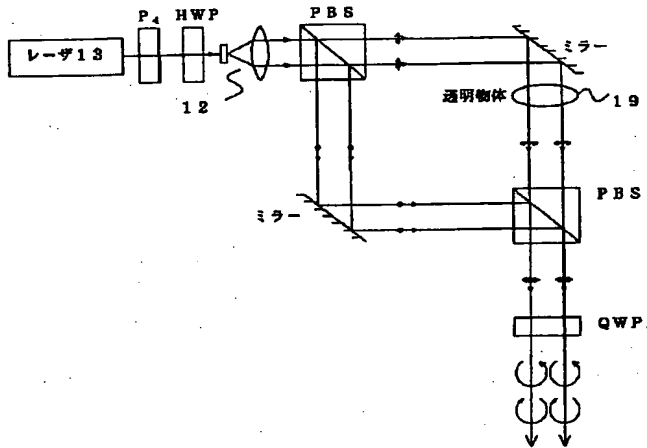
【図3】



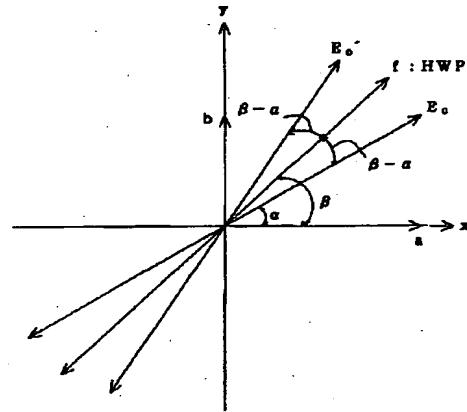
(5)

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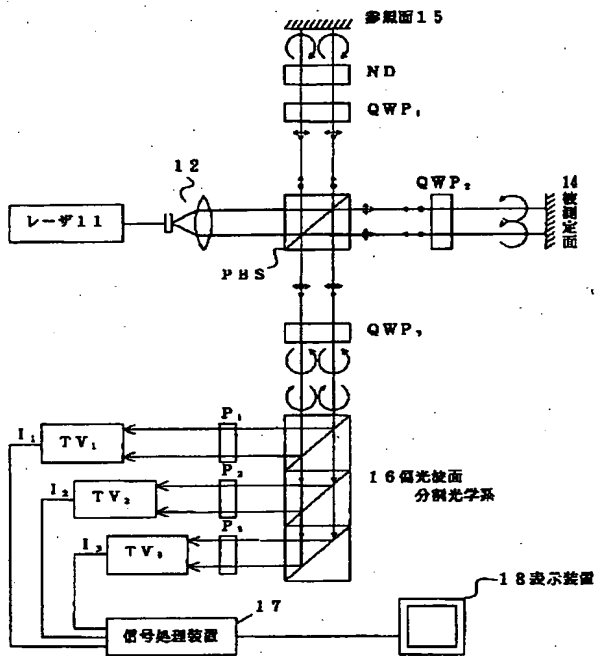
【図2】



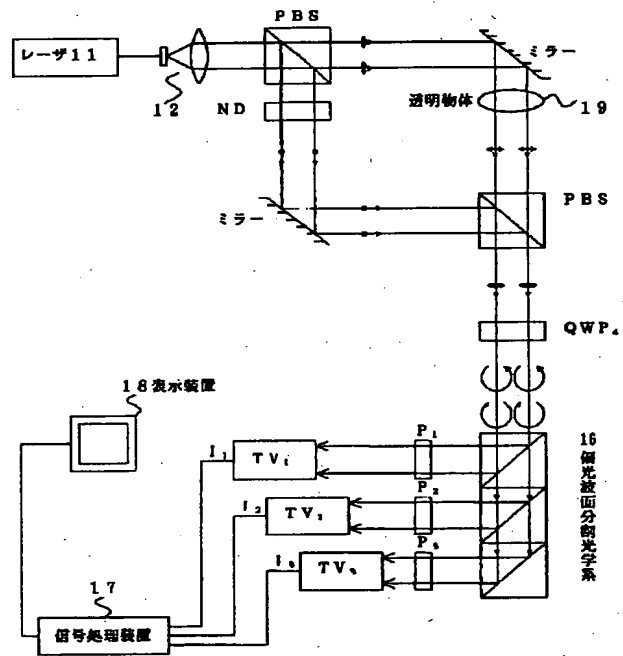
【図4】



【図5】



【図6】



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CLAIMS

[Claim(s)]

[Claim 1] An aspheric surface interference metering device which is characterized by providing the following and which measures a configuration of said specimen plane based on interference of the reflected light in a specimen plane of an aspheric surface configuration, and the reflected light in respect of criteria reference A field configuration error measurement means to search for a configuration error over said criteria reference side of said specimen plane through interference with the reflected light in respect of [said] criteria reference, and the reflected light in said specimen plane A maintenance means to hold said specimen plane pivotable to the circumference of a measuring beam shaft A cat's-eye reflector which forms a cat's-eye reflective condition of the shape of zona orbicularis by measuring beam irradiated towards said specimen plane An operation means negate the error resulting from the wave-front configuration of said measuring beam irradiated by said specimen plane based on the data of said field configuration error measurement means in two conditions which made an angle of rotation of the circumference of said measuring beam shaft of said specimen plane 0 times and 180 degrees, and the data which carried out wave-front composition and obtained data of said field configuration error measurement means in a cat's-eye reflective condition of the shape of said zona orbicularis, and search for the configuration of said specimen plane

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001] [The technical field to which invention belongs] This invention relates to the aspheric surface interference metering device which measures the specimen plane configuration of the aspheric surface using interference of light.

[0002] [Description of the Prior Art] For example, the Z-axis is used as an optical axis and the cross-section configuration in $Y = 0$ flat surface is [Equation 1].

$$Z = X^2 / R / \{1 + (1 - \kappa X^2 / R^2)^{1/2}\} + C_0 X^4 + C_6 X^6 + C_8 X^8 + C_{10} X^{10} \dots \text{Formula (1)}$$

the case where the configuration error (the geometric configuration error and profile irregularity error from a layout value) of an analyte side is measured using an interferometer in the case of the specimen plane which has the high order aspheric surface configuration which came out and used the secondary aspheric surface expressed as the base -- the so-called null -- interference measurement is performed.

[0003] such null -- the null which has an aspheric surface configuration equivalent to the aspheric surface which is specimen plane 4a of the *-ed lens 4 about the plane wave injected from the main part 101 of an interferometer, and the main part 101 of an interferometer as the equipment used for interference measurement is shown in drawing 3 -- the null for changing into a wave front -- it has the -izing element 102. Image formation locations differ in the direction of an optical axis with the function of the distance from an optical axis, and the flux of light which carries out incidence to the Nur-ized element 102 is designed so that a close echo may be carried out at right angles to specimen plane 4a of the *-ed lens 4.

[0004] When the usual condenser lens is used as this Nur-ized element 102, the so-called activity of a FIZO lens is difficult. it is because it must be inevitably alike and the Fizeau side must also be made into the aspheric surface, if specimen plane 4a is the aspheric surface when it is going to make the reflected light from the last side of a condenser lens, and the reflected light from specimen plane 4a interfere. therefore, as a criteria reference side for interfering with specimen plane 4a, a TOWAIMAN mold is adopted as the main part of an interferometer, and the reference beam side carried out 2 ****s by the beam splitter inside the main part of an interferometer is equipped, or (a graphic display is omitted) it is shown in drawing 3 as a false Fizeau mold interferometer -- as -- null -- the high-degree-of-accuracy plate (FIZO flat) 9 which has criteria reference side 9a will be inserted between a -izing element and the main part of an interferometer.

[0005] Anyway, between a criteria reference side and analyte side 4a, it is not avoided that the factor which disturbs the wave front of a measuring beam exists, but it needs to cope with these factors carefully. What is necessary is just to adopt the Nur-ized element of a zone plate mold, in order to eliminate this factor.

[0006] [Problem(s) to be Solved by the Invention] However, even if the ideal Nur wave front as a layout value which is expressed with a formula (1) is formed in a position, if only the constant rate which exists in the direction of an optical axis of an interferometer from a position is displaced in order that ordinary light may go straight on, the Nur wave front will change the geometric configuration of the aspheric surface. Specifically, each coefficient of a formula (1) will deviate from a layout value. However, the so-called interference fringe of "striped Isshiki" will be obtained by installing only the amount by chance as it with the more nearly same specimen plane 4a in the location where only the above-mentioned constant rate displaced the specimen plane 4a, if the geometric configuration has deviated from a layout value.

[0007] the null constituted as this showed by drawing 3 -- only from the interference fringe obtained with an interferometer, it is theoretically impossible to measure the aspheric surface configuration of specimen plane 4a to accuracy, and it shows that it is necessary to also grasp the location of the direction of an optical axis of specimen plane 4a to accuracy.

[0008] Furthermore, even if the location of specimen plane 4a is able to be decided to accuracy, when the Nur wave front in a position itself has deviated from a layout value this time, there is a problem that proofreading of the Nur wave front itself is also needed.

[0009] The object of this invention eliminates the error resulting from the wave-front configuration of a measuring beam, and is to offer the aspheric surface interference metering device which can carry out configuration measurement of the exact aspheric surface.

[0010] [Means for Solving the Problem] If it matches and explains to drawing 1 and drawing 2 which show a gestalt of 1 operation, invention according to claim 1 will be applied to an aspheric surface interference metering device which measures a configuration of specimen plane 4a based

on interference of the reflected light in specimen plane 4a of an aspheric surface configuration, and the reflected light in respect of criteria reference. And field configuration error measurement means 1 and 6 to search for a configuration error over a criteria reference side of specimen plane 4a through interference with the reflected light in respect of criteria reference, and the reflected light in specimen plane 4a, A maintenance means 5 to hold specimen plane 4a pivotable to the circumference of the measuring beam shaft X1, Cat's-eye reflector 4a which forms a cat's-eye reflective condition of the shape of zona orbicularis by measuring beam irradiated towards specimen plane 4a, Data of a field configuration error measurement means in two conditions which made an angle of rotation of the circumference of the measuring beam shaft X1 of specimen plane 4a 0 times and 180 degrees, It is based on data which carried out wave-front composition and obtained data of the field configuration error measurement means 1 and 6 in a cat's-eye reflective zona-orbicularis-like condition. The above-mentioned object is attained by having an operation means 6 to negate an error resulting from a wave-front configuration of a measuring beam irradiated by specimen plane 4a, and to search for a configuration of specimen plane 4a.

[0011] In addition, although drawing of a gestalt of implementation of invention was used by term of above-mentioned The means for solving a technical problem explaining a configuration of this invention in order to make this invention intelligible, thereby, this invention is not limited to a gestalt of operation.

[0012] [Embodiment of the Invention] Hereafter, the gestalt of 1 operation of the aspheric surface interference metering device by this invention is explained using drawing 1 and drawing 2. The main part of an interferometer with which 1 injects a plane wave in drawing 1 (a), the reference side body with which, as for 9, criteria reference side 9a was formed, The Nur-ized element which changes into the Nur wave front the plane wave which 2 was injected from the main part 1 of an interferometer, and penetrated the reference side body 9, The Nur-ized element maintenance adjustment device in which 3 holds the Nur-ized element 2, the *-ed lens, with which, as for 4, high order aspheric surface 4a was formed, The *-ed lens maintenance adjustment device in which 5 supports the *-ed lens 4 pivotable in the direction of the circumference of an optical axis, the arithmetic unit, with which 6 computes the profile irregularity error of the *-ed lens 4 in response to the picture signal from the main part 1 of an interferometer, and 7 are displays (monitor) which display the result of an operation by the arithmetic unit 6.

[0013] 8 is a laser length measuring machine which measures the location of the direction of an optical axis of the *-ed lens maintenance adjustment device 5, and is equipped with cube-corner-reflector 8b made removable [the laser length measuring machine 8] in laser light source 8a and the *-ed lens maintenance device 5, reference mirror 8c for length measurement, and 8d of laser beam detection equipment.

[0014] After the plane wave injected from the main part 1 of an interferometer penetrates the reference side body 9, it is changed into the Nur wave front by the Nur-ized element 2. null -- the null formed of the-izing element 2 -- interference measurement of specimen plane 4a is attained to a wave front by carrying out alignment of the specimen plane 4a of the *-ed lens 4 to a position according to the *-ed lens maintenance adjustment device 5. Alignment is performed by carrying out the monitor of the image pick-up of the interference fringe by the CCD camera built in the main part 1 of an interferometer.

[0015] The measuring beam shaft X1 of this interference measurement system is guaranteed by carrying out ball push of the Nur-ized element 2 on hardware criteria (datum-level criteria of a lens-barrel). In addition, in order to guarantee the measuring beam shaft X1 more strictly, it is necessary to arrange with the measuring beam shaft X1 the medial axis of the distortion which is not avoided by the usual interferometer photometry system. Moreover, in order to perform high-degree-of-accuracy measurement, it is desirable to install the migration shaft of a migration device in an optical axis X1 and parallel.

[0016] The interference fringe formed in the interior of the main part 1 of an interferometer is pictured by the CCD camera built in the main part 1 of an interferometer, and the picture signal is inputted into an arithmetic unit 6. The information on specimen plane 4a is beforehand inputted into an arithmetic unit 6, and it has the function to calculate and memorize a coefficient required for an operation, the device in which the picture signal from the CCD camera within the main part 1 of an interferometer is changed into optical-path-difference data, and the function that analyzes optical-path-difference data based on the coefficient mentioned above, and computes the profile irregularity error of specimen plane 4a. And the profile irregularity error (measurement result) of specimen plane 4a called for with the arithmetic unit 6 is displayed on a display 7.

[0017] The **ed lens maintenance adjustment device 5 in which the **ed lens 4 is held It consists of part I material 5a, part II material 5b, and part III material 5c, and part I material 5a in which the **ed lens 4 was attached receives part II material 5b. A tilt, Sliding is made that it can shift and possible, part II material 5b is made rotatable in the direction of the circumference of an optical axis X1 to part III material 5c, and sliding of part III material 5c is enabled [that a tilt and a shift are possible and] to the migration device in which it does not illustrate. And after sliding part I material 5a and making the aspheric surface shaft of specimen plane 4a of the **ed lens 4 once in agreement with the axis of rotation of part II material 5b by adopting such structure, Next, when the axis of rotation of part II material 5b was made in agreement with an optical axis X1 by part III material 5c and part II material 5b is rotated to part III material 5c, it becomes possible to rotate the **ed lens 4, without the aspheric surface shaft of specimen plane 4a shifting from an optical axis X1.

[0018] Moreover, part III material 5c is made movable in the optical-axis X1 direction through the migration device in which it does not illustrate, and can adjust the location of the optical-axis X1 direction of the **ed lens 4 by using this migration device.

[0019] As shown in drawing 1 , the location of the optical-axis X1 direction of the **ed lens 4 is measured by the laser length measuring machine 8 through the location of the optical-axis X1 direction of the **ed lens maintenance device 5. Although the laser length measuring machine 8 is illustrated one set in drawing 1 , the laser length measuring machine 8 is actually formed in two places by setting a symmetry axis as an optical axis X1, and an Abbe error can be removed by taking such arrangement. With the equipment of the gestalt of this operation, although the direct monitor of the specimen plane 4a cannot be carried out, the need of measuring the location of specimen plane 4a directly depending on the measuring accuracy demanded may arise.

[0020] Since the measurement value measured by the laser length measuring machine 8 is fed back to the migration device of the **ed lens maintenance device 5 through a non-illustrated control unit, it is made controllable [the location of the optical-axis X1 direction of the **ed lens 4].

[0021] The procedure in the case of carrying out configuration measurement of specimen plane 4a using <the procedure of measurement>, next drawing 2 with the configuration measuring device of the gestalt of this operation constituted as mentioned above is explained. The measurement procedure mentioned later applies the technique (John Wiley & Sons, 426 pages - 429 pages of 1978) for proofreading absolutely the profile irregularity of the spherical surface which Jensen/Bruning and others advocated to the aspheric surface.

[0022] First, the **ed lens maintenance adjustment device 5 is adjusted, and the aspheric surface shaft of specimen plane 4a of the **ed lens 4 and the axis of rotation of part II material 5b are made in agreement with the measuring beam shaft X1. And it is [Equation 2] when the profile irregularity data of specimen plane 4a measured by the arrangement which shows the angle of the direction of the circumference of the optical axis X1 of the **ed lens 4 to drawing 2 (a) when considering as the angle (theta= 0) of arbitration is set to D1.

$D1 = F(0) + W(0) + S(0) \dots \text{Formula (2)}$

It comes out. Here, F is the profile irregularity error of the criteria reference side of an interferometer, and expresses the error of criteria reference side 9a in drawing 1 . Moreover, the

error given to measurement of a profile irregularity error with the gaging system with which W includes the profile irregularity error of specimen plane 4a, and S includes an interferometer and the Nur-ized element 2 is expressed. Furthermore, the subscript in a parenthesis expresses the angle of rotation theta of specimen plane 4a of the circumference of the measuring beam shaft X1, the angle shown by theta= 0 as mentioned above is zero criteria set as arbitration at the time of the first measurement, and the angle when rotating specimen plane 4a 180 degrees is expressed with theta=pi.

[0023] Next, although the *-ed lens maintenance adjustment device 5 is operated and the *-ed lens 4 is rotated 180 degrees to the circumference of the measuring beam shaft X1 as shown in drawing 2 (b), the aspheric surface shaft of specimen plane 4a does not shift from the measuring beam shaft X1 as mentioned above. Therefore, it is [Equation 3] when the profile irregularity data of specimen plane 4a when rotating the *-ed lens 4 180 degrees is set to D2.

$$D2=F(0)+W(\pi)+S(0) \dots \text{Formula (3)}$$

It comes out. In addition, it is related with the measurement data of D1 and D2. the time of rotating the *-ed lens 4 -- the location of specimen plane 4a -- null, although it is necessary to measure the location of the measuring beam shaft X1 direction of specimen plane 4a in order to realize high-degree-of-accuracy measurement since it becomes impossible to take correlation with D1 and D2 when it displaces in the measuring beam shaft X1 direction to a wave front This location is measured by the laser length measuring machine 8.

[0024] It continues, and as shown in drawing 2 (d), the cat's-eye reflective condition in the *-ed lens 4 is formed about the flux of light injected from the Nur-ized element 2. Since the light which Nur-ized element 2' becomes the usual FIZO lens, and is injected after this forms a focus when specimen plane 4a[of *-ed lens 4'] is the spherical surface temporarily, as shown in drawing 2 (c), it is possible to realize a cat's-eye reflective condition. since [however,] criteria reference side 2a is the aspheric surface -- null -- a wave front -- a spherical wave -- not but -- therefore, it is theoretically impossible to realize a cat's-eye reflective condition at a time. Then, as shown in drawing 2 (d), measurement data D3i in two or more cat's-eye reflective conditions is divided and measured according to an individual by moving the *-ed lens 4 in the optical-axis X1 direction, and wave-front composition based on each data D3i is performed. The measurement data [in / by wave-front composition / a cat's-eye reflective condition] D3 is [Equation 4].

$$D3=\sigma D3i \dots \text{Formula (4)}$$

It can be alike and can ask more. Here, measurement data D3 has been obtained by connecting zona-orbicularis-like measurement data D3i which has a superposition portion so that those superposition portions of **** may suit most.

[0025] In addition, since it is not theoretically avoided that spherical aberration rides unless the zona-orbicularis-like data of each D3i prepares data D3i of a countless individual and connects it, it cannot be overemphasized that the amendment is needed. Although measurement of the location of specimen plane 4a is needed like a **** reflective condition for the amendment, it is measurable with the laser length measuring machine 8.

[0026] In a cat's-eye reflective condition, for the outward trip and return trip of the flux of light, since it comes to the location which serves as the symmetry of revolution mutually to the measuring beam shaft X1, D3 is [Equation 5].

$$D3=(F(0)+F(\pi))/2+S(0) \dots \text{Formula (5)}$$

It can be alike and can express more. Therefore, W(0) is [Equation 6] by the formula (2), the formula (3), and the formula (5).

$$W(0)=(D1+D2-D3-D3)/2 \dots \text{Formula (6)}$$

It can be found by carrying out. Although this operation is performed by the arithmetic unit 6, the portion which added the underline shows the data made to rotate profile irregularity error data

180 degrees within an arithmetic unit 6. Namely, [Equation 7]

$$D2=F(\pi)+W(0)+S(\pi) \dots \text{Formula (7)}$$

$D3 = (F(\pi) + F(0)) / 2 + S(\pi) \dots$ Formula (8)

It comes out.

[0027] In addition, **** 11 shown in drawing 1 (b) may be used instead of using specimen plane 4a as a reflector, in case the cat's-eye reflective condition shown in drawing 2 (c) is formed.

5 [0028] As explained above, in the aspheric surface interference metering device of the gestalt of this operation The measurement data D1 and D2 in two conditions of having rotated specimen plane 4a 180 degrees mutually, Since the configuration of specimen plane 4a is computed based on the data D3 which carried out wave-front composition and obtained measurement data D3i in a cat's-eye reflective zona-orbicularis-like condition null -- the configuration of the-izing element 10 2, and null -- the effect of the configuration error of the measurement wave front resulting from a location gap of the installation location of the-izing element 2 etc. can be eliminated, and exact configuration measurement of specimen plane 4a is attained.

15 [0029] [Effect of the Invention] Since he is trying to negate the error resulting from the wave-front configuration of a measuring beam based on the data of the field configuration error measurement means in two conditions of having rotated the specimen plane of each other 180 degrees, and the data which carried out wave-front composition and obtained the data of the field configuration error measurement means in a cat's-eye reflective zona-orbicularis-like condition according to this invention as explained above, the configuration of a specimen plane can be measured to accuracy.

[Translation done.]

*** NOTICES ***

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30 3. In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

35 [Drawing 1] It is drawing in which being drawing showing the gestalt of 1 operation of the aspheric surface interference metering device by this invention, and showing drawing in which (a) shows the whole gestalt of 1 operation, and the cat's-eye reflective condition of having formed (b) by ****.

40 [Drawing 2] Drawing showing the measurement procedure by the aspheric surface interference equipment of the gestalt of operation shown in drawing 1.

[Drawing 3] Drawing showing the optical arrangement in the case of performing configuration measurement of the aspheric surface in conventional equipment.

[Description of Notations]

1 Main Part of Interferometer

45 4 ** -ed Lens

4a Specimen plane

5 ** -ed Lens Maintenance Adjustment Device

6 Arithmetic Unit

[Translation done.]

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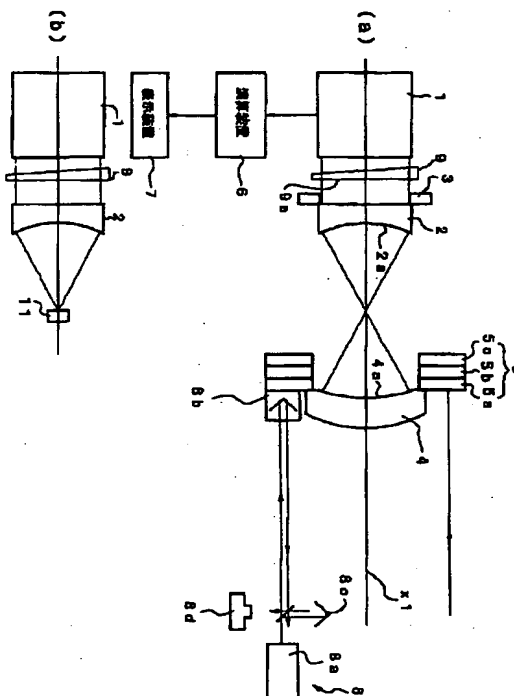
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(54) 【発明の名称】 非球面干渉計測装置

(57) 【要約】

【課題】 測定光の波面形状に起因する誤差を排除し、正確な非球面の形状測定をすることができる非球面干渉計測装置を提供する。

【解決手段】 被検面4aを互いに180度回転させた2つの状態における面形状誤差のデータと、輪帯状のキャッツアイ反射状態における面形状誤差のデータを波面合成して得たデータとに基づき、被検面4aに照射される測定光の波面形状に起因する誤差を打ち消して被検面4aの形状を求める。



【特許請求の範囲】

【請求項1】 非球面形状の被検面での反射光および基準参照面での反射光の干渉に基づいて前記被検面の形状を測定する非球面干渉計測装置において、
前記基準参照面での反射光と前記被検面での反射光との干渉を介して前記被検面の前記基準参照面に対する形状誤差を求める面形状誤差計測手段と、
前記被検面を測定光軸回りに回転可能に保持する保持手段と、
前記被検面に向けて照射される測定光による輪帯状のキャッツアイ反射状態を形成するキャッツアイ反射面と、
前記被検面の前記測定光軸回りの回転角を0度および180度とした2つの状態における前記面形状誤差計測手段のデータと、前記輪帯状のキャッツアイ反射状態にお

$$Z = X^2 / R / \{ 1 + (1 - \kappa X^2 / R^2)^{1/2} \} + C_{04} X^4 + C_{06} X^6 + C_{08} X^8 + C_{10} X^{10} \quad \cdots \text{式(1)}$$

で表される2次非球面をベースとした高次非球面形状を有する被検面の場合、被検体面の形状誤差（設計値からの幾何学的な形状誤差および面精度誤差）を干渉計を用いて測定する場合には、いわゆるヌル干渉計測が行われている。

【0003】このようなヌル干渉計測に使用する装置は、図3に示すように、干渉計本体101と、干渉計本体101から射出される平面波を被検レンズ4の被検面4aである非球面と等価な非球面形状を有するヌル波面に変換するためのヌル化素子102とを備える。ヌル化素子102に入射する光束は光軸からの距離の関数で光軸方向に結像位置が異なり、被検レンズ4の被検面4aに垂直に入射するように設計されている。

【0004】このヌル化素子102として通常の集光レンズを使用した場合、いわゆるフィゾーレンズの使用が困難である。なぜならば、集光レンズの最終面からの反射光と被検面4aからの反射光とを干渉させようとした場合、被検面4aが非球面であれば必然的にフィゾー面も非球面としなければならないからである。したがって被検面4aと干渉するための基準参照面としては、干渉計本体にトワイマン型を採用し、干渉計本体内部のビームスプリッターで2分割された参照光側に装着するか（図示は省略）、もしくは疑似フィゾー型干渉計として、図3に示すようにヌル化素子と干渉計本体の間に基準参照面9aを有する高精度平板（フィゾーフラット）9を挿入することになる。

【0005】いずれにしても、基準参照面と被検体面4aとの間には、測定光の波面を乱す要因が存在することが避けられず、これらの要因に注意深く対処する必要がある。この要因を排除するためには、ゾンプレート型のヌル化素子を採用すればよい。

【0006】

【発明が解決しようとする課題】しかしながら、たとえば、式(1)で表されるような設計値通りの理想的なヌ

ける前記面形状誤差計測手段のデータを波面合成して得たデータとに基づき、前記被検面に照射される前記測定光の波面形状に起因する誤差を打ち消して前記被検面の形状を求める演算手段とを備えることを特徴とする非球面干渉計測装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、非球面の被検面形状を光の干渉を用いて測定する非球面干渉計測装置に関する。

【0002】

【従来の技術】例えば、Z軸を光軸とし、Y=0平面での断面形状が、

【数1】

ル波面が所定の位置に形成されても、通常光は直進するために、所定の位置から干渉計の光軸方向にある一定量だけ変位すれば、そのヌル波面は非球面の幾何学的な形状を変えてしまう。具体的には、式(1)の各係数が設計値から乖離することになる。しかるに、たまたま被検面4aの方もそれと同じ量だけ設計値から幾何学的な形状が乖離していれば、その被検面4aを上述の一定量だけ変位した位置に設置することにより、いわゆる「縞一色」の干渉縞が得られてしまう。

【0007】これは、図3で示すように構成されたヌル干渉計で得られる干渉縞だけからは、被検面4aの非球面形状を正確に測定することが原理的に不可能であり、被検面4aの光軸方向の位置も正確に把握する必要があることを示している。

【0008】さらに、たとえ被検面4aの位置が正確に確定できたとしても、今度は所定の位置におけるヌル波面自身が設計値から乖離している場合には、ヌル波面そのものの校正も必要になるという問題がある。

【0009】本発明の目的は、測定光の波面形状に起因する誤差を排除し、正確な非球面の形状測定をすることができる非球面干渉計測装置を提供することにある。

【0010】

【課題を解決するための手段】一実施の形態を示す図1および図2に対応づけて説明すると、請求項1に記載の発明は、非球面形状の被検面4aでの反射光および基準参照面での反射光の干渉に基づいて被検面4aの形状を測定する非球面干渉計測装置に適用される。そして、基準参照面での反射光と被検面4aでの反射光との干渉を介して被検面4aの基準参照面に対する形状誤差を求める面形状誤差計測手段1、6と、被検面4aを測定光軸X1回りに回転可能に保持する保持手段5と、被検面4aに向けて照射される測定光による輪帯状のキャッツアイ反射状態を形成するキャッツアイ反射面4aと、被検面4aの測定光軸X1回りの回転角を0度および180

度とした2つの状態における面形状誤差計測手段のデータと、輪帯状のキャッツアイ反射状態における面形状誤差計測手段1, 6のデータを波面合成して得たデータとに基づき、被検面4aに照射される測定光の波面形状に起因する誤差を打ち消して被検面4aの形状を求める演算手段6とを備えることにより上述の目的が達成される。

【0011】なお、本発明の構成を説明する上記課題を解決するための手段の項では、本発明を分かり易くするために発明の実施の形態の図を用いたが、これにより本発明が実施の形態に限定されるものではない。

【0012】

【発明の実施の形態】以下、図1および図2を用いて本発明による非球面干渉計測装置の一実施の形態について説明する。図1(a)において、1は平面波を射出する干渉計本体、9は基準参照面9aが形成された参照面物体、2は干渉計本体1から射出され参照面物体9を透過した平面波をヌル波面に変換するヌル化素子、3はヌル化素子2を保持するヌル化素子保持調整機構、4は高次非球面4aが形成された被検レンズ、5は被検レンズ4を光軸回りの方向に回転可能に支持する被検レンズ保持調整機構、6は干渉計本体1からの画像信号を受けて被検レンズ4の面精度誤差を算出する演算装置、7は演算装置6による演算結果を表示する表示装置(モニタ)である。

【0013】8は被検レンズ保持調整機構5の光軸方向の位置を計測するレーザ測長器であり、レーザ測長器8はレーザ光源8aと、被検レンズ保持機構5に着脱可能とされたコーナークューブ8bと、測長用参照ミラー8cと、レーザ光検出装置8dとを備える。

【0014】干渉計本体1から射出される平面波は、参照面物体9を透過した後、ヌル化素子2によりヌル波面に変換される。ヌル化素子2により形成されたヌル波面に対し、被検レンズ4の被検面4aを被検レンズ保持調整機構5により所定の位置にアライメントすることにより、被検面4aの干渉計測が可能となる。アライメントは干渉計本体1に内蔵されたCCDカメラによる干渉縞の撮像をモニターすることにより行う。

【0015】この干渉計測系の測定光軸X1は、ヌル化素子2を金物基準(鏡筒の基準面基準)で玉押しすることにより保証している。なお、より厳密に測定光軸X1を保証するためには、通常の干渉計測光学系では避けられないディストーションの中心軸を測定光軸X1と揃える必要がある。また、高精度測定を行うためには、移動機構の移動軸を光軸X1と平行に設置しておくことが望ましい。

【0016】干渉計本体1の内部に形成された干渉縞は、干渉計本体1に内蔵されたCCDカメラにより撮像され、その画像信号は演算装置6に入力される。演算装置6には被検面4aの情報が予め入力され、演算に必要

な係数を演算して記憶する機能と、干渉計本体1内のCCDカメラからの画像信号を光路差データに変換する機構と、上述した係数に基づいて光路差データを解析し、被検面4aの面精度誤差を算出する機能とを有する。そして演算装置6で求められた被検面4aの面精度誤差(測定結果)が表示装置7に表示される。

【0017】被検レンズ4を保持する被検レンズ保持調整機構5は、第1部材5a、第2部材5bおよび第3部材5cからなり、被検レンズ4が取り付けられた第1部材5aは第2部材5bに対してティルト、シフトが可能で摺動可能とされ、第2部材5bは第3部材5cに対して光軸X1回り方向に回転可能とされ、第3部材5cは、不図示の移動機構に対してティルト、シフトが可能で摺動可能とされている。そしてこのような構造を採用することにより、一旦、第1部材5aを摺動させて被検レンズ4の被検面4aの非球面軸を第2部材5bの回転軸と一致させた後、次に、第3部材5cにより第2部材5bの回転軸を光軸X1と一致させると、第2部材5bを第3部材5cに対して回転させたときに、被検面4aの非球面軸が光軸X1からずれることなく被検レンズ4を回転させることが可能となる。

【0018】また第3部材5cは不図示の移動機構を介して光軸X1方向に移動可能とされており、この移動機構を用いることによって被検レンズ4の光軸X1方向の位置を調整することができる。

【0019】図1に示すように、被検レンズ4の光軸X1方向の位置は被検レンズ保持機構5の光軸X1方向の位置を介してレーザ測長器8により計測される。図1ではレーザ測長器8が1台のみ図示されているが、実際には光軸X1を対称軸として2箇所にレーザ測長器8が設けられており、このような配置を採ることによりアッペ誤差を取り除くことができる。本実施の形態の装置では、被検面4aを直接モニタすることはできないが、要求される測定の精度によっては被検面4aの位置を直接計測する必要が生ずる場合もある。

【0020】レーザ測長器8により計測された計測値は、不図示の制御装置を介して被検レンズ保持機構5の移動機構にフィードバックされるので、被検レンズ4の光軸X1方向の位置が制御可能とされている。

【0021】<測定の手順>次に、図2を用いて、以上のように構成された本実施の形態の形状測定装置により被検面4aの形状測定をする場合の手順について説明する。後述する測定手順はJensen/Bruningらが提唱した球面の面精度を絶対校正するための手法(John Wiley & Sons, 1978の426頁~429頁)を非球面に応用したものである。

【0022】まず最初に、被検レンズ保持調整機構5を調整して、被検レンズ4の被検面4aの非球面軸および第2部材5bの回転軸を測定光軸X1と一致させる。そして被検レンズ4の光軸X1回り方向の角度を任意の角

度 ($\theta=0$) としたときの図2(a)に示す配置で測定される被検面4aの面精度データをD1とすると、

$$D1 = F(0) + W(0) + S(0) \quad \dots \text{式(2)}$$

である。ここで、Fは干渉計の基準参照面の面精度誤差であり、図1における基準参照面9aの誤差を表している。また、Wは被検面4aの面精度誤差、Sは干渉計およびヌル化素子2を含む測定システムにより面精度誤差の測定に与える誤差を表す。さらに括弧内の添字は、測定光軸X1回りの被検面4aの回転角度 θ を表し、上述のように $\theta=0$ で示される角度は、最初の測定時に任意に設定されるゼロ基準であり、被検面4aを180度回

$$D2 = F(0) + W(\pi) + S(0) \quad \dots \text{式(3)}$$

である。なお、D1およびD2の測定データに関しては、被検レンズ4を回転させた時に被検面4aの位置がヌル波面に対して測定光軸X1方向に変位するとD1とD2との相関が取れなくなるため、高精度測定を実現するためには、被検面4aの測定光軸X1方向の位置を計測する必要があるが、この位置はレーザ測長器8により計測される。

【0024】つづいて、図2(d)に示すように、ヌル化素子2から射出された光束について被検レンズ4でのキャッツアイ反射状態を形成する。図2(c)に示すように、仮に被検レンズ4の被検面4aが球面であるとした場合には、ヌル化素子2は通常のフィゾーレンズとなり、これから射出される光は焦点を形成するので、キャッツアイ反射状態を実現することが可能である。しかし基準参照面2aは非球面であるためヌル波面は球面波でなく、したがってキャッツアイ反射状態を1度を実現することは原理的に不可能である。そこで、図2(d)に示すように被検レンズ4を光軸X1方向に移動させることにより、複数のキャッツアイ反射状態で

$$D3 = (F(0) + F(\pi)) / 2 + S(0) \quad \dots \text{式(5)}$$

により表すことができる。したがって、式(2)、式(3)および式(5)により、W(0)が、

$$W(0) = (D1 + D2 - D3 - D3) / 2 \quad \dots \text{式(6)}$$

として求まる。この演算は演算装置6により行われるが、下線を付加した部分は面精度誤差データを演算装置

$$D2 = F(\pi) + W(0) + S(\pi) \quad \dots \text{式(7)}$$

$$D3 = (F(\pi) + F(0)) / 2 + S(\pi) \quad \dots \text{式(8)}$$

である。

【0027】なお、図2(c)に示すキャッツアイ反射状態を形成する際に、被検面4aを反射面として用いる代りに、図1(b)に示す材子11を用いてもよい。

【0028】以上説明したように、本実施の形態の非球面干渉計測装置では、被検面4aを互いに180度回転させた2つの状態における測定データD1およびD2と、輪帯状のキャッツアイ反射状態における測定データD3iを波面合成して得たデータD3とに基づき、被検面4aの形状を算出しているため、ヌル化素子2の形状やヌル化素子2の設置位置の位置ずれ等に起因する測定

【数2】

転させた時の角度は、 $\theta=\pi$ で表される。

【0023】次に、図2(b)に示すように、被検レンズ保持調整機構5を操作して被検レンズ4を測定光軸X1回りに180度回転させるが、上述のように、被検面4aの非球面軸は測定光軸X1からずれることはない。したがって、被検レンズ4を180度回転させた時の被検面4aの面精度データをD2とすると、

【数3】

測定データD3iを個別に分割して測定し、個々のデータD3iに基づいた波面合成を行う。波面合成により、キャッツアイ反射状態における測定データD3は、

【数4】

$$D3 = \sum D3i \quad \dots \text{式(4)}$$

により求めることができる。ここでは、重畳部分を有する輪帯状の測定データD3iを、それらの重畳部分が最も辻褄が合うように繋ぎ合わせることで測定データD3を得ている。

【0025】なお、個々のD3iの輪帯状データは、無数のデータD3iを用意して繋ぎ合せない限り、球面収差が乗ることが原理的に避けられないため、その補正が必要となるのは言うまでもない。その補正のために、球心反射状態と同様、被検面4aの位置の計測が必要となるが、レーザ測長器8により計測することができる。

【0026】キャッツアイ反射状態では、光束の往路と復路とは測定光軸X1に対して互いに回転対称となる位置に来るので、D3は、

【数5】

$$D3 = (F(0) + F(\pi)) / 2 + S(0) \quad \dots \text{式(5)}$$

【数6】

6内で180度回転させたデータを示す。すなわち、

【数7】

波面の形状誤差の影響を排除でき、被検面4aの正確な形状測定が可能となる。

【0029】

【発明の効果】以上説明したように、本発明によれば、被検面を互いに180度回転させた2つの状態における面形状誤差計測手段のデータと、輪帯状のキャッツアイ反射状態における面形状誤差計測手段のデータを波面合成して得たデータとに基づき、測定光の波面形状に起因する誤差を打ち消すようにしているので、被検面の形状を正確に測定することができる。

【図面の簡単な説明】

【図1】本発明による非球面干渉計測装置の一実施の形態を示す図であり、(a)は一実施の形態の全体を示す図、(b)は材料により形成したキャッツアイ反射状態を示す図。

【図2】図1に示す実施の形態の非球面干渉装置による測定手順を示す図。

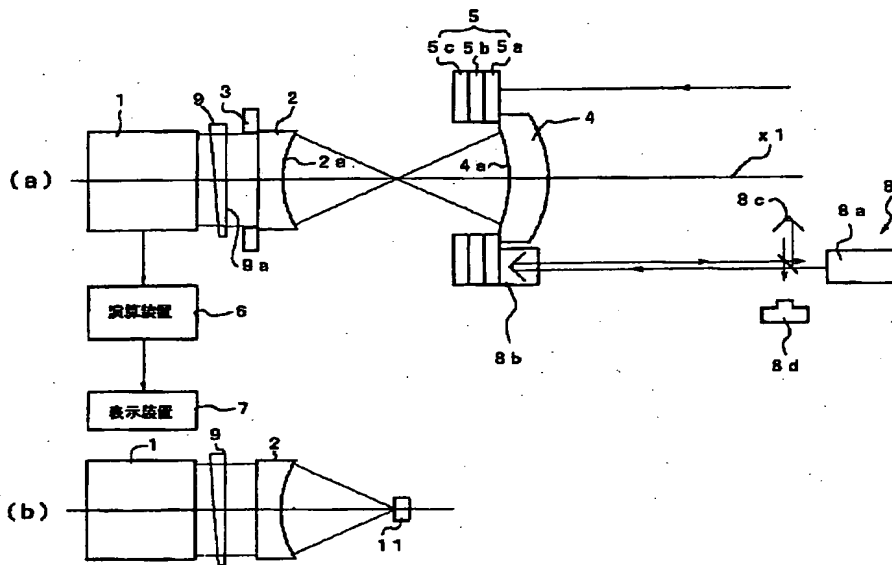
【図3】従来の装置における非球面の形状測定を行う場

合の光学配置を示す図。

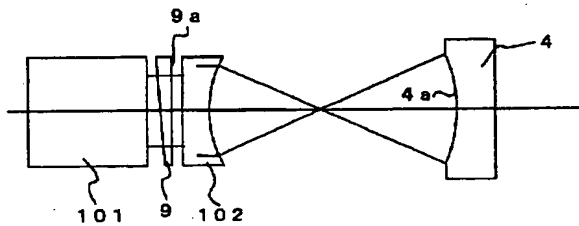
【符号の説明】

- 1 干渉計本体
- 4 被検レンズ
- 4a 被検面
- 5 被検レンズ保持調整機構
- 6 演算装置

【図1】



【図3】



【図2】

